SIGNAL TIMING SCHEDULE FOR TRAFFIC CONTROL PLAN

SF Police Dept

REPORT BY SPECIAL COMMITTEE TO
TRAFFIC LAW ENFORCEMENT BOARD

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SIGNAL TIMING SCHEDULE FOR TRAFFIC CONTROL PLAN

Report and Recommendations

To

SAN FRANCISCO TRAFFIC LAW ENFORCEMENT BOARD

By

SPECIAL COMMITTEE

Representing:

Police Department Traffic Bureau - City of San Francisco

Bureau of Engineering, Traffic Division - City of San Francisco

California State Automobile Association

San Francisco Traffic Survey Committee

Co-operating With

Department of Electricity - City of San Francisco

San Francisco, California
June 15, 1929

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TABLE OF CONTENTS

	Page
Letter of Transmittal	II
Introductory Statement	1
General Traffic Requirements	2
General Types of Signal Timing	3
Basic Factors Influencing Timing	6
Adjustments in the Time Schedule	8
The Signalized Area of Downtown San Francisco	10
Future Improvements	19
The Recommended Schedule of Signal Timing For The Downtown Area of San Francisco	24

PLATES

Plate A Pattern of Traffic Streets-- Districts North and South of Market Street	10
Plate I. A Typical Signal Schedule and Flow Diagram for North-South Traffic	21
Plate II. Signal Timing for Market Street	23

REF 388.4131 Si26

Signal timing schedule
for traffic control
1929.

San Francisco Traffic Survey Committee

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June 15, 1929

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San Francisco Traffic Law Enforcement Board,
San Francisco, California.

Gentlemen:

On July 24, 1928 your undersigned special committee was appointed to prepare a plan for a progressively timed system of traffic signal control on Market Street. At the meeting of the Board held on November 13, 1928 the committee submitted its first report dated October 31, 1928 and entitled: "Market Street Traffic Control Plan". The recommendations contained therein related to the placement of traffic control equipment and associated street structures. The report was unanimously approved by the Board, and the work provided for therein is now nearing completion by the City Departments having jurisdiction.

The first report pointed out the importance of properly timing the traffic signals, and recommended that a comprehensive study of signal timing be undertaken for the entire down town area. The committee was instructed at the meeting of the Board on November 13, 1928 to undertake such a comprehensive timing study and to report its recommendations for the proper timing of the signal system.

Your committee herewith respectfully submits its second report, dated June 15, 1929, entitled: "Signal Timing Schedule For Traffic Control Plan", wherein complete recommendations are given for the specific timing of all signals in the down town area.

The committee believes that these recommendations, calculated with precision upon the basic factors of distance and time and upon its best judgment as to suitable speeds for the entire area and the practical handling of traffic across and along Market Street, offer as complete a solution of the problems of traffic signal control as can be devised in advance.

Due to the complexities of street design it has been found after exhaustive study that ideal conditions as to speed and continuity of traffic movement cannot be attained by any combination of signal timing. The report specifically shows

the reasons why certain compromises must be made in joining together into one harmonious traffic time pattern two dissimilar block patterns, separated by a diagonal street having wholly different traffic characteristics of its own. In the judgment of the committee the timing schedule recommended will give the greatest degree of continuity and rapidity of traffic movement consistent with safety for the whole area, and with the least disadvantages.

Attention is called to the section of the report relating to the future possibilities of further refinements in the timing of pedestrian signals along Market Street to gain still greater street efficiency than is provided in the schedule now recommended. These refinements, however, are not recommended at this time, as the committee feels that the schedule here presented should first be established and properly adjusted through experience. After that is accomplished, it is recommended that careful study be made of further refinements in timing the special pedestrian signals.

Respectfully submitted,

Charles Goff
Captain, Police Traffic Bureau — Chairman

Chief, Department of Electricity

City Traffic Engineer

Manager, Highways Bureau,
California State Automobile Ass'n

Resident Engineer, San Francisco
Traffic Survey Committee

Introductory Statement

The timing of the traffic signal system for the downtown area of San Francisco is a task that demands the closest analysis of existing conditions and careful application of the basic principles of signal timing. Any schedule of timing which will bring about an improvement over existing conditions should be considered. That schedule, however, which will allow traffic to flow at the highest speed commensurate with safety, with a minimum of delay and/or conflict, and with a maximum continuity of movement is the one which should be evolved.

In order to develop such an ideal schedule it is necessary to incorporate experience with study. Careful consideration and analysis of the problem will indicate a preliminary schedule of timing. That schedule must then be tested for the discrepancies which can only be brought out in practice. Correction of the minor troubles which may develop should not be made upon hurried inspection or hastily developed alterations. Especially for a street system like that of downtown San Francisco, it must be remembered that the schedule of timing resulting from a long study produces a time pattern of traffic flow which is extremely delicately balanced. Any change in the schedule should be made only after there has been a careful analysis of the ramifications which lie back of that change.

The proposed schedule of traffic signal timing set forth in this report is one which is designed to meet the demands of traffic flow and is recommended only after an exhaustive study of existing conditions. Because of the peculiar arrangement of streets found in and near the central traffic district

of San Francisco, it is necessary to use three distinct cycle lengths. It is highly important, therefore, that the proposed schedule be followed very closely in order to fit together the district north of Market Street, the district south of Market Street and Market Street itself. Unquestionably, each of these sections of the downtown area possesses distinctly different characteristics and demands different treatment.

The pedestrian signal system to be used in conjunction with the vehicular signals on Market Street is a distinct innovation in traffic signaling. In order to avoid confusion in the public mind and in order to train pedestrians to follow the special signals provided for them, it is felt that the pedestrian signals should work at first synchronously with the vehicular signals. A refinement of this system, which will add materially to the efficiency of intersection operation, is discussed in this report.

Finally, there are certain general rules of signal operation which have become standardized throughout the country. These standards are desirable and well suited to San Francisco.

General Traffic Requirements

The utility of a traffic signal system depends upon the accuracy with which the system is adjusted or timed to fit traffic requirements. An examination of the characteristics of traffic flow shows that there are certain requirements which should be met in any schedule of signal timing. These requirements, which must be satisfied insofar as fluidity and safety of

traffic movement is concerned, may be set forth as follows:

First: The signals should be timed so as to permit the continuous flow of traffic at the speed which is normal for the area traversed.

Second: The signals should be timed so as to prevent or reduce to a minimum the simultaneous flow of conflicting streams of traffic--both vehicular, and vehicular with pedestrian.

Third: The signals should be timed so as to prevent or reduce to a minimum the accumulation of traffic in any block or series of blocks.

Fourth: The signals should be timed in accordance with the relative volume of traffic flow per lane at an intersection.

Fifth: The signal system should be timed so as to vary with the traffic speed and volume throughout the traffic day.

General Types of Signal Timing

There are several types of signal timing systems, which are generally classified as: Independent, Synchronized, Limited Progressive, and Flexible Progressive. These systems are defined by the American Engineering Council on Street Traffic Signs, Signals, and Markings as follows:

> "(a) Independent. The operation of the signal is not related to the operation of any other signal. Isolated intersections that are controlled by independent traffic signals, not related in operation to any other signals, cannot be said to form a traffic control system.
>
> "(b) Synchronized. A type of coordinated control in which all signals show the same color in the same direction simultaneously.

"(c) Limited Progressive. A form of progressive system in which the signals are grouped, the alternate groups showing opposite colors in a given direction and all signals changing simultaneously.

"(d) Flexible Progressive. A form of progressive system in which the operation of each signal is determined by the traffic requirements of the intersection and which in addition provides for the continuous movement of traffic."

In the order of preference these systems are discussed by the American Engineering Council as follows:

Flexible Progressive System:

"The flexible progressive system is the best for the coordination of signals along a single street and is the only one that is well adapted to the control of signals on a number of adjacent streets that form a district. Its only limitation is that the complete cycle of changes must be of the same duration for all the intersections controlled. It has the following advantages:

"(1) It permits the continuous movement of traffic at approximately a predetermined speed on both through and cross streets.

"(2) It makes possible the adjustment of the timing of each signal to the variations in the flow of traffic at the particular intersection controlled by that signal.

"(3) It discourages speeding, because it forces the driver of a vehicle to make frequent stops if he exceeds the speed determined for the system.

"(4) It permits modification of the timing throughout a considerable area to adjust it to the differences in the movement of traffic at different hours of the day."

Limited Progressive System:

"The limited progressive system is an adaptation of the synchronized system obtained by so changing the wiring of alternate signals or groups of signals that each signal or group as seen from the same direction shows the color having the meaning opposite to that conveyed by the adjacent signal or group. Under the conditions for which this system is satisfactory it has the following advantages:

"(1) It permits the continuous movement of traffic on a single street at approximately a predetermined speed, subject to the limitations stated in paragraph (c) below.

"(2) It discourages speeding, because a vehicle is forced to make frequent stops if it exceeds the speed for which the system is arranged.

"It has the following disadvantages:

"(1) It is not well adapted to a street having blocks of unequal length.

"(2) It requires equal time intervals for through traffic and for cross traffic, so that too much time is devoted to cross traffic on a street where there is a greater volume of through traffic.

"(3) If the signals are grouped it reduces the capacity of the street between points where the color changes, because only the vehicles that enter the first intersection of a group during the first part of the green interval can move continuously."

Synchronized System:

"The synchronized system is simple, but it has the following disadvantages:

"(1) It necessitates the stopping of all traffic simultaneously in one direction, so that the continuous movement of vehicles is impossible and the overall speed and the average speed are low.

"(2) On streets traversed by electric railways, it increases the peak power load, because of the simultaneous starting of many street cars.

"(3) It encourages speeding in order to pass as many intersections as possible before a change of signals.

"(4) The timing is based on the flow of traffic at the most congested intersection, and as the timing at all intersections must be the same, the traffic at the other intersections is unnecessarily delayed."

The flexible progressive system is the preferred type and is the system for which provisions have been made in San Francisco. There are no practical limitations in this system insofar as the timing of the signals is concerned.

Basic Factors Influencing Timing

Signal timing is essentially the establishment of a series or sequence of traffic flow intervals which occur in accordance with the relationship of traffic speeds and distances to be traversed between controlled intersections. The width and arrangement of streets, the speed of traffic flow and the sequence of traffic "GO" and "STOP" periods are bound so closely together in their relationship that it is impossible to vary one without changing either one or both of the other factors.

The width and arrangement of streets are usually the basis or foundation upon which the schedule of timing is arranged. Inasmuch as traffic control does not ordinarily contemplate changes in street pattern, and since such changes are ordinarily extremely costly and would probably be decided upon many other considerations than signal control of traffic, it is the normal thing insofar as traffic signal timing is concerned to regard the street system as fixed and unchangeable. This immediately fixes the factor of distances, which is basic in arriving at a schedule of signal timing.

If the street pattern is accepted as rigidly fixed, there are only two variables which remain to decide the schedule of timing. The speed of traffic flow and the arrangement of the time series.

The speed of traffic flow is ordinarily limited in its variation. It is desirable to maintain as high a speed as possible, yet one which is commensurate with safety and efficiency of traffic flow. Ordinarily the upper limit of traffic speed on a signalized street is about twenty-five miles per hour.

Speeds in excess of this value are hazardous because of turning movements, even where there is only a slight amount of pedestrian movement. If a street is found to entertain even an ordinary amount of turning movement, it is probable that an average speed of twenty-five miles per hour is higher than the speed with which the normal traffic stream will flow.

Considering safety alone, the lowest value of speed which can be considered is of course nominal. An effort to prevent congestion and bad public reaction will result ordinarily in speeds at least in excess of five miles per hour. The type of traffic to be moved of course affects the minimum speed. Above all, the signals should be timed so as to keep traffic moving continuously.

In order to determine the approximate speeds which are suitable for a signalized street, it is best to make actual test runs over the signalized street. These tests should not only show the average speed maintained, but should also show the time lost in delays, the nature of the delays, the total time required and the running speed. The facts brought out by the speed tests indicate the speeds which under existing conditions are normal for the street to be controlled. If such tests indicate much signal delay, it should be remembered that not only the average speed but the running speed as well are somewhat low due to acceleration and deceleration of traffic. The speeds thus indicated coupled with the judgment of experience permit a rather definite decision as to what speed should be contemplated in the schedule of timing.

With the street pattern accepted as fixed, and with the

traffic speed decided, the one remaining factor of time sequence is resultant. Any schedule of timing arrived at upon this basis is sound, and any variation from this schedule is necessarily a compromise.

Adjustments in the Time Schedule

In the design of a timing schedule for traffic signals, as in nearly every field of design, certain adjustments are found to be necessary. Some of these adjustments are only minor and do not involve any serious consequences, whereas others are so important and so pyramiding in their result that any change however slight may affect the entire system profoundly. Some compromises in the design may be predetermined, whereas others can be made only with experience.

If the block length and traffic speed indicate the sequence of traffic "STOP" and "GO" intervals in cyclic changes of less than forty seconds, it is probable that there will need to be a change which will increase the cycle length. This change may mean reduced speed or multiple block movement, or both. There is a strong presumption against multiple block movement where a heavy traffic flow exists, because it will be found that the movement obtained will be jerky and the average speed no greater than single block movement. On streets where intersections occur at short block intervals, but where moderately high speeds are otherwise natural, there arises one of the most aggravating and serious problems of signal timing.

Where it is found, on account of street width and/or

heavy pedestrian movement, that long clearance periods are necessary, it may be essential to increase the length of cycle and reduce the speed of traffic movement in order to increase the amount of "GO" period over a length of time, and hence accommodate a greater volume of traffic.

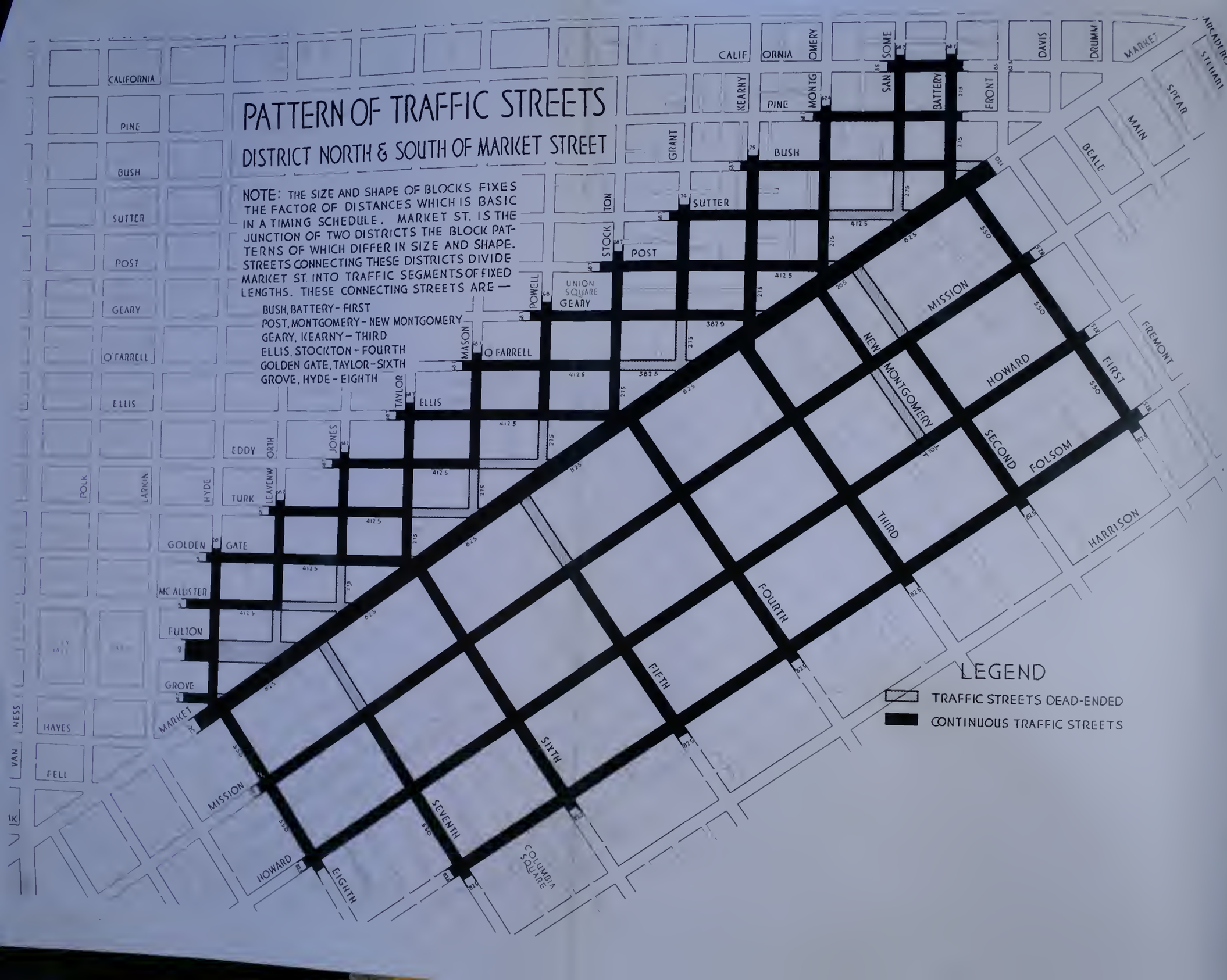
Where it is found that cycles of different lengths are required for definite areas which must be matched into an homogeneous traffic pattern, it is most important that the ratio of one cycle length to the other vary in exact accordance with simple fractions expressed by digits not greater than 3 or possibly 4; e.g. 1/3, 2/3, 1/2, etc.

Where different cyclic arrangements exist as parts of such a matched homogeneous traffic pattern it is imperative that the clearance time expressed in percent of cycle be the same for each cycle; in other words, the time given over to clearance for a given time, say one hour, must be the same for the entire controlled area.

Where two or more speeds are desirable for a street carrying mixed traffic, it is to be remembered that progressive movement may be obtained at speeds expressed as the odd reciprocals of the highest speed; i.e., if the highest speed for which the street is set is taken as unity, then progressive movement may take place at speeds of 1/3, 1/5, 1/7 or 1/9 of the highest speed.

Where it is found that extra long blocks and slow traffic seems to dictate a cycle of too great length, it may be found advisable to reduce the cycle length to such value as to permit continuous flow of 1/3 or 1/5 the highest value of speed for which the street is set.

PLATE A


PATTERN OF TRAFFIC STREETS
DISTRICT NORTH & SOUTH OF MARKET STREET
NOTE: THE SIZE AND SHAPE OF BLOCKS FIXES THE FACTOR OF DISTANCES WHICH IS BASIC IN A TIMING SCHEDULE. MARKET ST. IS THE JUNCTION OF TWO DISTRICTS THE BLOCK PATTERNS OF WHICH DIFFER IN SIZE AND SHAPE. STREETS CONNECTING THESE DISTRICTS DIVIDE MARKET ST. INTO TRAFFIC SEGMENTS OF FIXED LENGTHS. THESE CONNECTING STREETS ARE —
BUSH, BATTERY - FIRST
POST, MONTGOMERY - NEW MONTGOMERY
GEARY, KEARNY - THIRD
ELLIS, STOCKTON - FOURTH
GOLDEN GATE, TAYLOR - SIXTH
GROVE, HYDE - EIGHTH
CALIFORNIA
PINE
BUSH
SUTTER
POST
GEARY
O'FARRELL
ELLIS
EDDY
TURK
GOLDEN GATE
MC ALLISTER
FULTON
GROVE
HAYES
FELL
MARKET
MISSION
HOWARD
GRANT
KEARNY
MONTGOMERY
SANSOME
BATTERY
FRONT
DAVIS
DRUMM
MARKET
ARCADE
STUART
SPEAR
MAIN
BEALE
FREMONT
FIRST
SECOND
THIRD
FOURTH
FIFTH
SIXTH
SEVENTH
EIGHTH
STOCKTON
POWELL
MASON
TAYLOR
JONES
LEAVENWORTH
HYDE
LARKIN
POLK
VAN NESS
UNION SQUARE
COLUMBIA SQUARE
MISSION
NEW MONTGOMERY
HOWARD
FOLSOM
HARRISON
LEGEND
TRAFFIC STREETS DEAD-ENDED
CONTINUOUS TRAFFIC STREETS

The Signalized Area of Downtown San Francisco

From the foregoing elements of traffic signal timing, attention is turned to the downtown area of San Francisco. An analysis of the conditions which exist there and of the pattern of traffic movement which must be dealt with, will lead to certain definite conclusions regarding a schedule of signal timing.

The street plan of the controlled area has been discussed in the preceding report of the committee: "Market Street Traffic Control Plan". A brief review of the street system from the timing point of view is, however, necessary for the purposes of this report.

It is extremely important to note the size and shape of the blocks, for this fixes the factor of distances which, as has been pointed out, is basic in any timing schedule. Plate A shows that there are two distinct and separate systems of block formations which are joined together by Market Street, which street is entirely different from either system.

The signalized district north of Market possesses rather uniform dimensioned blocks about 275 feet by 412.5 feet, separated by streets about 68.75 feet in width. In other words, the units of distances traversed without crossing signal control average about 343.75 feet and 480.25 feet. It will be noted that the traffic conditions in this district are somewhat uniform in themselves but that the conditions here manifest are entirely different from Market Street or the section south of Market Street.

A similar study of the district south of Market Street shows the blocks to be about 550 feet by 825 feet and separated

[illegible] Bay [illegible] Section [illegible]

by streets 82.5 feet in width. In other words, the maximum units traversed without passing signals are 632.5 feet and 907.5 feet. As pointed out above, traffic flow in this area is distinct from the area north of Market Street or Market Street itself.

Market Street, the line on which the two distinct districts join, is a most irregular and unique street. Intersections are irregularly spaced along the street, and street car and pedestrian traffic flow is preponderant. The pattern of traffic flow formed by those intersections which permit the direct interchange of travel from one district to the other should be noted. It is of great importance in the timing schedule that such intersections as those formed by Sixth, Fourth, New Montgomery, et al, provide as closely as possible for continuous crosstown travel.

The factor of distance in the formation of the timing schedule is definitely fixed by the existing street plan. Summarizing the distance elements it is unquestionable that there are three distinct systems to be controlled in the downtown area. Each system is of sufficient importance in itself to demand a timing schedule suited to it without any serious compromise being forced because of the other districts. Yet the fact must not be overlooked that these three integral parts of the signal system must be welded into a working whole, which will form a homogeneous pattern of traffic time flow.

Attention is next turned to the factor of traffic speed in the downtown area. It has already been pointed out that the traffic characteristics of the three distinct parts of the signalized area are different from each other. This is true also in the case of traffic speed, which is a basic factor in the formation of the schedule.

Speed tests which have been made show that the average running traffic speed on those streets extending east and west and lying north of Market Street is about 12.5 miles per hour; while north and south streets in the same district carry traffic at about 10.9 miles per hour. These are the average speeds eliminating traffic signal and other delays. For the district south of Market similar traffic speed east and west is 14.6 miles per hour, and north and south 12.3 miles per hour. Market Street, on the other hand, flows at average speeds varying between 7.06 and 11.2 miles per hour.

As has been pointed out, the factors of distance and speed determine the time series arrangement of "STOP" and "GO" intervals or what is ordinarily termed cycle length. It is evident, if two districts of a system are dimensioned differently but operate nevertheless at speeds which though not of the same magnitude may be considered as equivalent when compared to block lengths or free distance for movement, that the same cycle length is applicable to both districts. However, if the blocks are so dimensioned that such natural speed equivalents cannot be produced by the same cycle length, then each part must be timed according to its individual needs, but harmonized so far as practicable with the other part.

The latter condition is found in the present problem. The speeds and dimensions of the section north of Market indicate a short cycle length of about 40 to 50 seconds; whereas the district south of Market requires a longer cycle length of about 60 to 80 seconds. Market Street, the key artery on which these two sections must be harmoniously joined, is very irregular and is

characterized by peculiar traffic conditions. Because of clearance periods and the nature of its load, Market Street indicates a still longer cycle.

In determining the relative lengths of cycle to be used for the three conditions, attention is called to the fact that there must necessarily be a compromise between the desired speeds and those speeds which will result when a satisfactory ratio of cycle lengths is established.

As was pointed out above, the ratio of cycle lengths to each other should be expressed by simple ratio; i.e., the ratio of the cycle length of a pair of adjacent sections should be one to two, two to three or some similar relationship expressed by digits less than four, or preferably three. This is highly important because if some such simple ratio does not hold, there will be a cumulative effect of discrepancies between the "GO" periods as traffic passes from one district to another. As a result of such discrepancies the traffic stream will not be regular or orderly in movement; and the total amount of delay experienced will be greater when the ratio is complex than when it is simple.

On the other hand, an effort should be made to establish cycles of such lengths as to be suited to the natural speed of traffic. Long cycles are adapted to slow speeds, and short cycles are adapted to higher speeds. The speeds which are desired of course must be compromised with the proper cyclic ratio.

From the values of speeds given above and upon the basis of practicable speeds and cycle lengths which would be suitable to the signalized area, the following speeds are proposed for normal traffic flow (i.e., between the morning rush and the evening rush of traffic):

First: It is proposed that for traffic flowing on those streets running east and west and lying north of Market Street, the speed should be about 14.5 miles per hour or some lesser speed which is possible and is expressed as one-third, one-fifth, etc., of the normal speed for which the street is set.

Second: That with the speed on the east and west streets as specified above, the north and south speed will be 10.5 miles per hour or some odd reciprocal of that speed.

Third: That for streets running east and west and lying south of Market Street the normal speed should be about 20.5 miles per hour, other possible speeds being the odd reciprocal of that speed.

Fourth: That with the speed on the east and west streets as specified above, the north and south speed in the district south of Market Street will be 14.4 miles per hour or some odd reciprocal of that speed.

Fifth: That Market Street be set at such value as to form a suitable compromise between the two districts referred to above and that the speed along Market Street should be about 8.5 miles per hour.

Sixth: That the same cyclic arrangement be used for the pedestrian signals as for the traffic signals on Market Street by operating the two sets synchronously for each intersection.

These speeds have been chosen with due regard for cycle lengths. The cycle lengths which will produce these speeds are: for the district north of Market Street 45 seconds; for the district south of Market Street 60 seconds; and for Market Street

90 seconds. It is noted that the ratio between the Market Street cycle and the cycle for the district north is one to two, and the ratio between Market Street and the other district south of Market is two to three.

The relationship of these cycle lengths signifies that every other wave of traffic from the north will flow south across Market Street in true progression, while every alternate wave must wait for a portion of the cycle length on Market Street. Similarly a part of the second wave from the south will flow in true progression, all of the third wave will flow in continuous movement except for a very slight delay, and the first wave together with part of the second wave must wait about 35 to 40 seconds. The sacrifice of true progression across Market Street is felt justified because normal speeds throughout the two districts and along Market Street are thus made possible. (See Plate No. 1 and its description.)

There are of course many possible arrangements of speeds and cycle lengths. Each has its advantages and disadvantages. If a single cycle length were chosen for the entire downtown area it would mean that the speeds north of Market would be too slow and the speeds south of Market and on Market would be too fast. Or if the cycle length chosen were suited to one district only, the other two parts of the system would suffer proportionally more. It is felt that the proposal given above will more closely approach the desired conditions with less sacrifice than any other combination.

Clearance periods which are cut out of each cycle length are, of course, necessary for reasons of safety and avoidance of

actual conflict. These clearance periods, however, from the point of view of congestion, result in inefficiencies which reduce the possible amount or volume of traffic flow. Safety is paramount in the decision, and the protection of the pedestrian is the governing factor in determining the amount of clearance period.

When pedestrian control is contemplated with the signal system, the length of the clearance period is determined by the length of time which is required for the average person to cross the roadway. In other words, to protect the pedestrian who is following signal control, we must prohibit cross flow of vehicular traffic while the pedestrian is in the roadway. Furthermore, the effect of starting pedestrians across a roadway with a green signal and then starting traffic to flow across their path before they can reach safety on the opposite curb, would be demoralizing to the entire plan of pedestrian regulation by automatic signals.

In order to reduce such clearance periods to a minimum, safety islands were recommended in the "Market Street Traffic Control Plan". Where it is feasible the pedestrians will now have safety islands located in the longer crosswalks where they may wait with safety until cross traffic is stopped. This feature will help materially in gaining efficiency and safety on Market Street. This practice is recommended for wide streets or long crosswalks by the American Engineering Council on Street Traffic Signs, Signals, and Pavement Markings. In passing it is interesting to note that such a safety island is quite properly termed by the French as an <u>isle of refuge</u>.

But even with reduced pedestrian crosswalk lengths on Market Street the clearance periods required there are the govern-

ing periods in clearance time to be set aside. It requires at least 14 seconds for a person to walk between curbs across Market Street. This means that a person must walk about 3.7 miles per hour, or 5.45 feet per second, which is slightly higher than normal speed. For those crosswalks which parallel Market Street it will require on the average at least 10 seconds to clear the pedestrian from cross traffic flow. A total therefore of 24 seconds per cycle is required for clearance period on Market Street.

Since 24 seconds out of every cycle is required to clear these intersections, it tends to further justify the long cycle on Market Street because the amount of time expressed in percent, which is set aside for clearance periods, will be less with a long cycle than with a short cycle for a given length of time or for a day. By cutting out 24 seconds from even the 90 second cycle for clearance period, 23.7 percent of the available time is lost in clearing the street for cross flow. This amount of time is imperative, however, to give pedestrians the protection and safety they have been promised.

In order to prevent the banking up of traffic at Market Street or along Market Street, the amount of traffic flow time must be about the same throughout the system. If it is assumed that there are as many left and right turns into a given street as there are out of that street, it is apparent that no more traffic can flow on that street than will pass at the heaviest intersection or those intersections which have the lowest amount of "GO" period. Hence, if 26.7 percent of the time is given over to clearances on Market Street, a similar amount of time should be

given over elsewhere. Therefore, for the intersections north of Market Street 12 seconds are required, or 6 seconds each way, and for the district south of Market 16 seconds are required, or 8 seconds each way.

The designing of the signal timing schedule to meet the fluctuations of traffic flow is a relatively simple matter. Inasmuch as the longer cycles give slower speeds with greater time flow and less proportion of cycle for clearance time, they are inevitably suited to slow heavy traffic. Short cycles are, on the other hand, adapted to light flow and speedy traffic. The amount of change in the cycle length and the times of day when these changes are desirable should be chosen largely from experience in the operation of the system. The speed tests are indicative of the changes in speed between rush and normal traffic. They furnish a guide as to the amount of fluctuation in speed. Some cities where flexible systems of traffic control have been installed find it necessary to change the system ten and eleven times a day, others find that fewer changes are better. Any change of the cycle lengths should be predicated solely upon traffic flow.

Regardless of the number of changes which are required, it is essential that the ratio of cycle lengths between districts remain rigidly constant unless there is a radical change in traffic conditions in one district which does not occur concomitantly with a similar change in the other districts. Market Street, due to the street car-pedestrian combination, may develop into the latter condition because of the human element involved in pedestrian regulation. Such a condition, however, is not expected.

Future Improvements

The proposals set forth above do not, it will be noticed, contemplate an immediate differentiation in timing between pedestrian signals and traffic signals on Market Street. It is realized that this adjustment should be accomplished as soon as practicable. The arrangement is subject to future refinements, but for the purpose of accustoming the walking public to the pedestrian signal system, it is felt that less confusion would exist if the pedestrian signals and vehicular signals work synchronously to start with, because this condition is what the public mind is now acquainted with. Once the pedestrians have become accustomed to the guidance given by the pedestrian signals, there can be certain refinements undertaken which are not now considered practicable.

The refinements referred to are made possible by actually introducing a phase shift in the pedestrian signals as compared to the cycle of the vehicular signals. The basis of such a shift is to stop the pedestrian movement earlier than the vehicular stream and hence reduce the clearance periods for vehicular traffic. With a reduction in the clearance period it will perhaps be possible to reduce the cycle length of the signals on Market Street and hence provide for greater frequency of opportunity of "GO". This refinement will undoubtedly lead to a better adapted control of Market Street, but it is hazardous to introduce it until such time as the pedestrians have learned to follow their own system of signals. ~~especially provided for them. The refined system will also be able to start the clockwise movement of pedestrians earlier than the counter clockwise movement. Such refinements are extremely desirable but are not recommended to be introduced at present. People have become accustomed to~~

walking across the roadways at the same times that vehicular traffic is flowing in the directions which they walk. To attempt to change this course of things, until such time as the walking public has learned to follow the pedestrian signal without regard for the vehicular signal, would lead to a certain amount of confusion. The pedestrian signals are an innovation in traffic signaling. The future employment of these signals with greater street efficiency, and the use of installed plant for years to come, demands that the soundest manner of introducing them be followed. a method of introduction which will result in a minimum of confusion.

PLATE I.

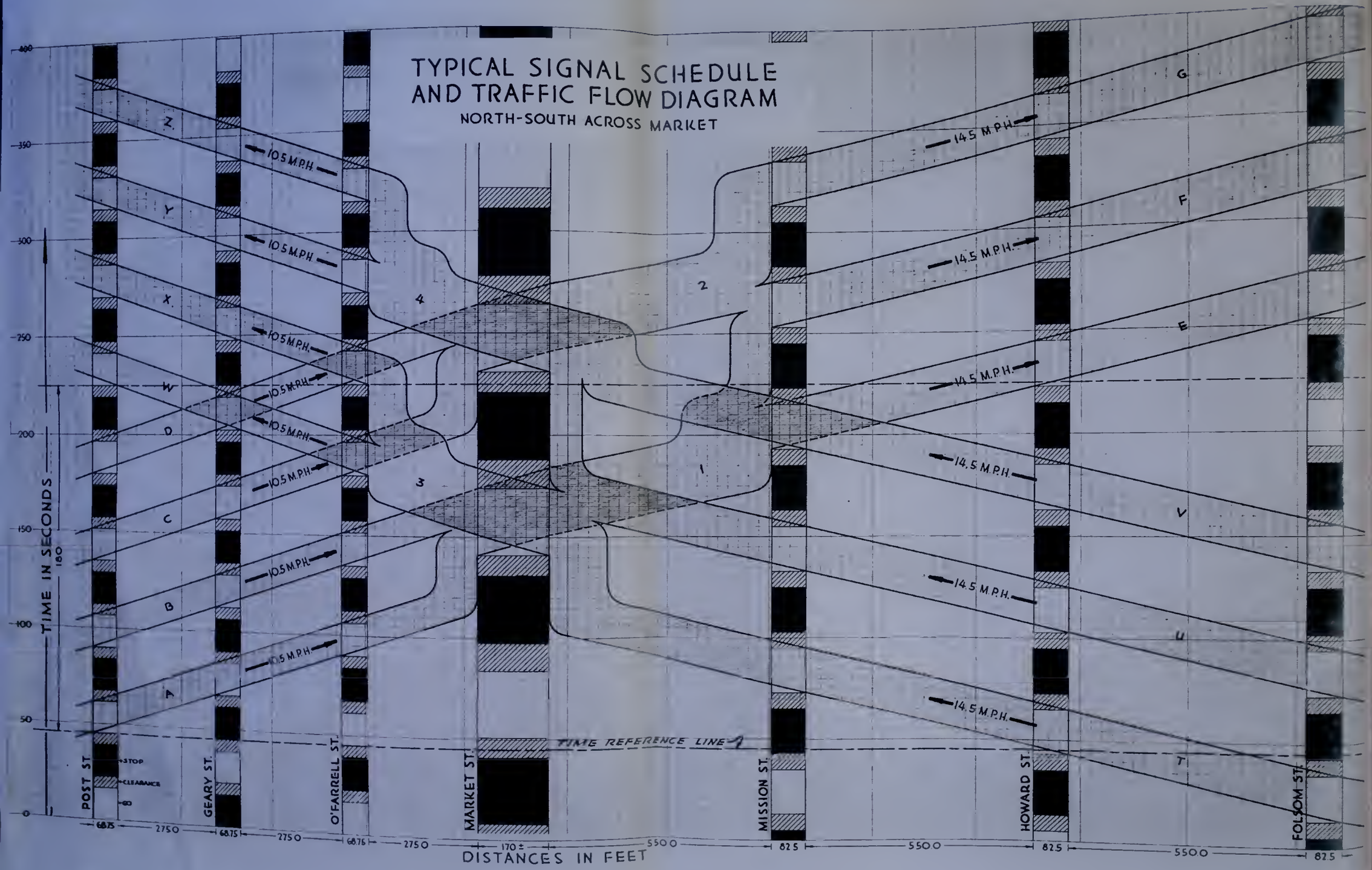

TYPICAL SIGNAL SCHEDULE
AND TRAFFIC FLOW DIAGRAM
NORTH-SOUTH ACROSS MARKET
TIME IN SECONDS
400
350
300
250
200
150
100
50
0
180
Z
Y
X
W
D
C
B
A
G
F
E
V
U
T
10.5 M.P.H.
14.5 M.P.H.
1
2
3
4
TIME REFERENCE LINE
STOP
CLEARANCE
60
POST ST.
GEARY ST.
O'FARRELL ST.
MARKET ST.
MISSION ST.
HOWARD ST.
FOLSOM ST.
68.75
2750
68.75
2750
68.75
2750
170±
5500
82.5
5500
82.5
5500
82.5
DISTANCES IN FEET

PLATE NO. I

A Typical Signal Schedule and Flow Diagram for North-South Traffic.

The manner of interchange of traffic or the traffic flow between the district north of Market and the district south of Market is shown in Plate No. I. It will be noted that the four traffic waves A, B, C and D join together at Market Street to form two waves Nos. 1 and 2 and continue to Mission Street where they break up into the three waves E, F and G south of Market. Similarly the three waves V, U and T from the district south of Market join to form the two waves Nos. 3 and 4 crossing Market Street and these in turn break up into the four waves W, X, Y and Z.

The operation referred to above repeats itself each 180 seconds or once each "master cycle".

It will be further noted that waves A and C are delayed 28 seconds at Market Street, while waves B and D continue across Market Street without delay. As the two waves Nos. 1 and 2 approach Mission Street, all of No. 1 is delayed 19 seconds and a part is held over for 30 seconds to join the first part of Wave No. 2, which crosses Mission without delay, the next cycle. The remainder of wave No. 2 is carried over to fill the third cycle at Mission Street. Further study of this plate will show similar delays for north bound traffic flow. The delays are not serious and it is felt that in order to obtain suitable speeds as pointed out above, the sacrifice of continuous movement for cross flow is well justified.

In order to maintain this relationship of traffic flow

PLATE NO. 2

A Typical Weekly Schedule and Plan
Outline for Work-Sheet Use.

the three cycles must be rigidly fixed relative to each other. If the master cycle is lengthened or shortened, a similar pattern of traffic flow at slower speeds will result, but only when the ratio of the cycles remains constant and the relative positions in time of these cyclic changes is constant.

PLATE II

PLATE NO. II

Signal Timing for Market Street

Because of the irregularities of Market Street a graphical presentation of the schedule of signal timing for that street is shown in Plate No. II. It will be noted that for setting the timer, those instants from the time reference line when north and south traffic is first given a complete "GO" signal, are given.

The waves of traffic shown have a magnitude of 33 seconds each way. The speeds are necessarily variable but hold very closely to present operating speeds of the street, and give an average value of about 8 to 9 miles per hour. The speed through the central district is lower than on the western part of the street due to heavy loading of street cars. The speed shown east of First Street can be increased with the adoption of a shorter cycle, which is only advisable after the pedestrian signal system is operated independently of the vehicular signals as explained before.

The division of cycle at each intersection as shown is suggested as suitable to start the system. It will perhaps be found advisable to change this division for some of those intersections which have not been signalized hertofore. Experience will indicate what these changes should be.

The inset shown indicates the signal schedule recommended if the Powell Street intersection is signalized instead of the Emporium crosswalk. The resulting traffic flow is shown if it is assumed that the Fourth Street and Fifth Street intersections are the controlling intersections of the speed as indicated.

Alcohol Tablets for Marine Stoves

Purchase of the investigation of Dexine Alcohol & Chemical Corporation of the Australia of alcohol tablets for use aboard is shown in Item No. 11. It will be noted that its use, for stoves, these tablets have the fuse advantage over wood and marine fuel in that when a sufficient, are clean.

The means of testing whether such a substitute of the same kind work well. The experts are unanimously satisfied for their ability to consume upwards of the stoves, and have an efficient value of about 2 to 3 cents per hour. The equal testing the relative ability to burn this or the kerosene used by stoves, is to insure their use of these tablets. The second stoves of Item Three may be accomplished with the addition of a shorter cooking ration is entirely independently of the necessity already in operation.

The sizable of depth of any investigation is shown by [illegible] to which the Bureau is still pressing [illegible] Further evidence is shown this service for those laboratory which only for some is carried service. Specific will indicate that these results about use.

The last above indicate the [illegible] Chemical Corporation [illegible] Dexine Chemical. The results indicate that because it is [illegible] that it [illegible] and fuel Stove [illegible] the [illegible] is to speed as indicated.

The Recommended Schedule of Signal Timing For The Downtown Area of San Francisco.

This schedule is recommended as suitable for the normal daytime traffic flow; i.e., between the morning and evening rushes.

For the district north of Market Street the cycle length should be forty-five (45) seconds. For the district south of Market Street the cycle length should be sixty (60) seconds. Market Street should be operated on a ninety (90) second cycle.

The "master cycle" of 180 seconds is composed of four cycles north of Market, two cycles on Market Street and three cycles south of Market. The master cycle should start at instant 0 for the district north of Market, at instant +6 seconds for Market Street, and at +28 seconds for the district south of Market. These times being measured from the time reference line should remain rigidly constant for the master cycle length given above. In case the master cycle is lengthened or shortened, the values of 0, 6 and 28 seconds will vary accordingly.

The beginning of each cycle within this master cycle should indicate a "GO" signal for traffic flowing north and south, as along such streets as Kearny Street and Third Street. The "GO" period in each direction for the district north of Market Street should be 16½ seconds and clearance periods of 6 seconds should follow each "GO" period.

The "GO" period in each direction south of Market Street should be 22 seconds each way with a clearance period of 8 seconds.

The "GO" periods for Market Street intersections are shown in Plate No. II and are variable.

The following intersections north of Market Street should start the first cycle in the master cycle as showing "GO" for north and south travel at instant 0 seconds, and this should be taken as the time reference point for setting all signals:

1. Powell and Ellis
2. Powell and Geary
3. Powell and Sutter
4. Stockton and O'Farrell
5. Stockton and Post
6. Grant and Geary
7. Grant and Sutter
8. Kearny and Post
9. Kearny and Bush
10. Kearny and California
11. Montgomery and Sutter
12. Montgomery and Pine

The following intersections north of Market should start the first cycle in the master cycle as showing a green or "GO" signal for traffic flowing north and south at instant 22.5 seconds after the time reference point of 0 seconds:

1. Powell and O'Farrell
2. Powell and Post
3. Stockton and Geary
4. Stockton and Sutter
5. Grant and Post
6. Grant and Bush
7. Kearny and Sutter
8. Kearny and Pine

9. Montgomery and Bush
10. Montgomery and California

The following intersections south of Market should start the first cycle in the master cycle as showing a green or "GO" signal for traffic flowing north and south at instant 28 seconds after the time reference point of 0 seconds:

1. Tenth and Mission
2. Eighth and Mission
3. Sixth and Mission
4. Fourth and Mission
5. New Montgomery and Mission
6. Second and Mission
7. Eleventh and Howard
8. Ninth and Howard
9. Seventh and Howard
10. Fifth and Howard
11. Third and Howard
12. First and Howard

The following intersections south of Market should start the first cycle in the master cycle as showing a green or "GO" signal for north and south traffic at instant 58 seconds after the time reference point of 0 seconds:

1. Eleventh and Mission
2. Ninth and Mission
3. Seventh and Mission
4. Fifth and Mission
5. Third and Mission

6. First and Mission
7. Tenth and Howard
8. Eighth and Howard
9. Sixth and Howard
10. Fourth and Howard
11. New Montgomery and Howard
12. Second and Howard
13. Third and Folsom

The intersections on Market Street listed below should start the first cycle in the master cycle as showing a green or "GO" signal for traffic flowing north and south at the following instants:

Intersection	Instant after time reference point the "GO" cycle for north and south flow begins
Van Ness - Eleventh	50 seconds
Tenth	6 "
Ninth	60 "
Eighth	6 "
Seventh	66 "
Jones	64 "
Sixth	6 "
Mason	56 "
Fifth	20 "
Powell	58 "
Emporium	70 "
Fourth	6 "
Grant	58 "
Third	6 "

Intersection	Instant after time reference point the "GO" cycle for north and south flow begins
Montgomery	54 Seconds
Second	56 "
Sansome	16 "
First	54 "
Fremont	22 "
Beale	68 "
Main	8 "
Spear	72 "

The schedule given above is suited to the normal flow of traffic. In order to reduce the traffic speeds, as may be sound suitable for rush traffic, it is recommended that the prime mover of the timer be slowed up so as to produce the suitable speed. Likewise, if it is found necessary to increase the speed of traffic flow throughout the district, the motor of the signal timer may be speeded up. It is extremely important, however, that all cycles change proportionately in order to maintain the same proportionate relationship of traffic flow; i.e., the ratio of one cycle to either of the other two must remain a constant.